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MAINTENANCE OPERATIONS IN MISSION ORIENTED PROTECTIVE POSTURE LEVEL IV (MOPPIV)

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Troop performance degradation due to the wearing of chemical protective equipment is a concern to military commanders. As a result of this concern a series of field studies were conducted in an attempt to quantify the effect that wearing mission oriented protective posture, level IV (all equipment worn and sealed) has on personnel performing tasks. Maintenance tasks are considered to be particularly difficult to perform while wearing protective equipment. To evaluate this situation and provide a

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quantitative estimate of the degradation, seven maintenance tasks were performed in a field environment, at moderate temperatures (40-68°F). The tasks included remove and replace M60A3 powerpack, M60A3 transmission, M109 Breech Block; repair M60 Machine gun, M901 ITV traverse mechanism and a FADAC printed circuit board. These operations were performed by several teams who alternated starts while wearing the standard battle dress uniform (BDU) and the MOPPIV ensemble. Individuals were highly motivated, in high physical readiness and psychologically prepared for the operation.

Data were analyzed using standard statistical procedures. A MOPPIV correction factor was defined as that value by which the time to complete a procedure in BDU should be multiplied to provide the time required to complete the task while wearing MOPPIV. These factors are:

Correction Factors for Wearing MOPPIV

Task	Factor	Probable Range
M60A3 Power Pack		
Remove	1.2	1.0-1.4
Replace	1.3	1.1-1.5
M60A3 Transmission		
Remove	1.4	1.1-1.7
Replace	1.1	0.9-1.4
M109 Breech Block		
Remove	1.2	1.1-1.4
Replace	1.3	1.1-1.5
M60 Machine Gun		
Barrel Group	1.4	1.3-1.6
Trigger Group	2.3	2.0-2.6
M901 Traverse Mechanism		
Remove	2.1	1.7-2.5
Replace	2.5	1.7-3.4
Recover M60A3	1.8*	0.8-3.1
FADAC Circuit Board	1.6	1.4-1.9

*Without Boots

The first time effect, that experience gained through repetition, is comparable in magnitude to the MOPPIV effect, an indication that training improves personnel performance while wearing this equipment. The protective overboot is a hazard in the mud and should be redesigned. Correction factors are used as a guide for performing tasks in the field. It should be noted, however, that these values do not reflect performance under continuous operations where other variables influence performance.

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I. INTRODUCTION

1. Background

Troop performance degradation due to chemical protective equipment has been of increasing concern to military commanders. This protective equipment is worn in one of four configurations referred to as mission oriented protective posture (MOPP) levels. The highest protective level, MOPPIV, in which all equipment is worn and sealed, is also the most bulky, cumbersome and restrictive mode. Personnel are protected at the expense of this encumbrance - a circumstance which results from impeded physiological functions such as vision, hearing, speaking, manual dexterity and others. This encumbrance produces degradation in the form of (usually) increased time to complete tasks and in some cases reduced accuracy. For the purposes of this evaluation time to complete a task was the only factor used in determining personnel degradation due to wearing MOPPIV. To quantify this degradation for the commander's use, in simulations, operations research and other studies of unit effectiveness and combat readiness, field studies are necessary.

This evaluation was performed in response to a requirement submitted to the Dugway Proving Ground (DPG) administered Chemical Biological Joint Contract Point and Test Program, referred to as DO-49, to conduct an evaluation to determine the effect that wearing MOPPIV has on personnel performing military tasks. Presently, the program includes several specific operational areas with additional emphases on operations during cold, moderate and hot temperatures. The Ballistic Research Laboratory (BRL) was contracted to make an evaluation of the performance decrement.

The Vulnerability/Lethality Division of the BRL has an extensive ongoing program for assessing the vulnerability of military systems on the integrated battlefield to include the effects of conventional, nuclear and chemical munitions on the effectiveness of various units. The model for this program is the Army Unit Resiliency Analysis (AURA) methodology.[1] AURA utilizes inputs from all areas which impact on the ability of a unit to accomplish a mission including the effect of wearing MOPPIV. Since degradation data has not generally been available and because of the need to include degradation performance in unit effectiveness studies,[2] the BRL is developing techniques to

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1. J.T.Klopcic, and L. K. Roach, "An Introduction to the Use of the Army Unit Resiliency Analysis (AURA) Methodology: Volume I," US Army Ballistic Research Laboratory, Memorandum Report No. 3384, September 1984.

estimate personnel degradation due to MOPPIV. In this report, "MOPPIV" refers to wearing of the equipment at level IV, and "MOPPIV Time" to the amount of time required to complete a task while wearing level IV.

A concern in interpreting field data is the need to quantify the degradation. It is not unusual to find subjective judgements made on the effect protective equipment has on individual performance, often with no real measurement of the effect or of the variation experienced. One purpose of this report is to provide a numerical estimate of the performance decrement resulting from wearing individual protective equipment.

This report presents the results of selected maintenance operations conducted at Aberdeen Proving Ground, Maryland in April and May 1984 under moderate to warm temperatures (63-84° F). A daily summary of temperature and relative humidity is included in Appendix A. Trials were performed by soldiers of the Student Brigade of the U.S. Ordnance Center and School, APG. Dugway Proving Ground was assisted by two contractors, Lockheed Engineering and Management Service Company, and Andrullis Research Corporation who cooperated in collecting the data and providing videotape coverage of all trials. Trials were performed during the daylight hours. Teams remained in MOPPIV without relief for each trial. Several tasks were performed (Table 1).

TABLE 1. Maintenance Operations

Task
Remove/Replace M60A3 Power Pack
Remove/Replace M60A3 Transmission
Remove/Replace M109 Breech Block
Recover M60A3 Tank
M60 Machine Gun Repair
M901 ITV Traverse Mechanism Repair

2. David W. Harris, "A Degradation Analysis Methodology for Maintenance," Master of Science Thesis, Georgia Institute of Technology, April 1985; Sponsor: C. Wick, BRL.

2. Objective

The primary objective of this program was to evaluate the operational capabilities and to estimate the degradation for personnel dressed in complete chemical protective ensemble (MOPPIV) performing selected maintenance tasks.

II. APPROACH

1. Overview

The measure of degradation for each performed task was the time difference between performing the task in Battle Dress Uniform (BDU) and MOPPIV. For these trials there were five teams for each task. Degradation measurements were made for team tasks, such as pulling the power pack, as well as individual tasks, such as repairing the gas cylinder on the M60MG. Observing each team was a trained military observer (Senior NCO) who timed each individual task and rated the overall operation. The tasks were measured in real time and recorded on a data sheet carried by the observer.

Individuals were trained in the appropriate military operational speciality (MOS) and were highly motivated. Teams did not have prior experience working together. Further, the teams did not have prior practice before completing the first trial. Teams were familiar with chemical protective equipment, but received no special prior instruction in the wearing or completing the above tasks while wearing MOPPIV.

Since these tests were repetitive, individuals gained experience as they progressed through the trials. In an effort to control and later estimate the experience effect, the order of start was noted; i.e., whether a team was in BDU or MOPPIV the first time it performed a trial. For the purposes of this analysis, all references to "first time effect" pertain to the first performance for each team.

For each trial, three items of data were recorded: first, the time to complete a task; second, the protective profile (BDU/MOPP); and third, whether it was the first trial or a subsequent one.

A multiple linear regression technique was used to estimate the effect of the chemical protective equipment and the effect of practice on the time to complete the various tasks.

2. Tasks/Procedures

a. **Remove/Replace M60A3 Power Pack.** A four-man crew performed this task (Table 2.) These crewmen were systems mechanics MOS 63N/63H. Each team performed once in BDU and once in MOPPIV. There was a one-hour break between the trial in BDU and the trial in MOPPIV. Within a trial a fifteen minute break, between removing and replacing the power pack, was given, during which the team stayed in uniform.

TABLE 2. M60A3 Power Pack

Event	Operation
1	Cover
2	Turret Connections
3	Accessory Connections
4	Power Pack

b. **Remove/Replace M60A3 Transmission.** This was a two-man task. The crew consisted of one experienced and one student member both trained as MOS 63H. The transmission was separated from the power pack and then replaced (Table 3). Each team completed the task once in BDU and once in MOPPIV except team 4 which performed the task once in BDU and twice in MOPPIV. A fifteen minute break was given between separation and rejoining the transmission during which, the crewmen did not remove the MOPPIV equipment. An hour break was taken between BDU and MOPPIV operations.

TABLE 3. M60A3 Transmission

Event	Operation
1	Shroud
2	Accessories
3	Mounting Bolts
4	Transmission

c. **Remove/Replace M109 Breech Block.** The crew consisted of two personnel, one experienced and one student, both trained as artillery repairmen, MOS 45L/45K. Each team performed the task four to eight times, depending upon the weather and the time to accomplish the task by individual teams. A total of thirty-five

completions were recorded. The task was conducted in two phases (Table 4), by removing the breech block and replacing it with no break between phases.

TABLE 4. M109 Breech Block

Event	Operation
1	Damper
2	Firing Mechanism
3	Breech Block

d. **Recover M60A3 Tank.** A disabled M60A3 tank was recovered by a four-man team utilizing a M88 recovery vehicle (Table 5). The team was composed of students trained as automotive repairmen MOS 63H/63N. The protective overboot became a hazard to the wearer due to the deep mud at the test site and was not used as part of the MOPPIV gear after trial M-1.

TABLE 5. M60A3 Tank Recovery

Event	Operation
1	Attach Tow Bar
2	Open Grill Doors and Remove Heat Shields
3	Disconnect Final Drives
4	Secure Grill Doors and Replace Heat Shield

e. **Repair M60 Machine Gun.** This was a one-man task simulating the field repair of the M60 machine gun (Table 6). Personnel were trained in small weapon repair MOS 45K performed this task in a tent located in a field environment.

TABLE 6. M60 Machine Gun

Event	Operation
1	Barrel Group
2	Trigger Assembly

f. **Repair M901 ITV Traverse Mechanism.** A one man task with personnel trained in MOS 45K disassembled and assembled a traverse mechanism (Table 7). The task was performed on a workbench in a tent located in a field environment.

TABLE 7. M901 ITV Traverse Mechanism

Event	Operation
1	Outer Gear and Snap Ring
2	Gear Assembly

g. **Repair FADAC Printed Circuit Board.** This was a one man task completed by students who were instrumentation repair personnel, MOS 34Y,44Y and 45G (Table 8).

TABLE 8. FADAC Printed Circuit Board

Event	Operation
1	Remove Protective Coating*
2	Resistor
3	Transistor
* Remove Event Only	

3. **Data Analysis Techniques**

a. **Multiple Linear Regression.** Regression analyses are used to quantify the relationship between variables where the value of one is affected by changes in others. The type of uniform worn and whether or not the event was completed for the first time, either in BDU or MOPPIV, are independent variables. A multiple linear regression allows a dependent variable to be estimated by quantifying the relationship to several independent variables. In this instance, time to complete a task is the effected or dependent variable. Interactions and variables not measured are reflected in the error term and include such effects as team work and leadership. An estimate of how well the regression estimates the dependent variable is expressed by the multiple correlation coefficient. Analysis then can be used to determine the effect of MOPPIV and the first time effect on the total time to complete a task.

For troop performance studies the regression expression is represented by:

$$T = T_o + a(x) + b(y) + e \quad (1)$$

Where "T" (the dependent variable) is the total time in minutes to complete a task, "T_o," (the intercept) is the practiced, unencumbered time, "x" (first independent variable) is the clothing type, "y" (second independent variable) is the order in which an event was started and "e" is the error term. The BDU or MOPP condition "x" is represented by either a "0" or a "1," respectively since it is assumed that the clothing contribution would be zero for BDU. Likewise, if a team was working an event for the first time "y" would be assigned a "1" and if the team has completed the event before or a "0" would be assigned since no first time effect would be present. The expression, without the error term, then becomes:

$$T = T_o + a + b \quad (2)$$

where "a" and "b" represent the correction in minutes for MOPPIV and practiced factors, respectively. Therefore, a team completing an event for the first time in BDU is expressed as:

$$T = T_o + b \quad (3)$$

A team completing an event in BDU more than twice would simply be "T_o," ($T = T_o$). By wearing MOPPIV this team would add a MOPPIV correction and be expressed as:

$$T = T_o + a \quad (4)$$

The event time for the same team completing the event for the first time and in MOPPIV would be expressed as:

$$T = T_o + a + b \quad (5)$$

b. **Aggregated Events.** Some tasks can be considered together or grouped as the result of similar physical functions. Tasks which are generally gross motor skills can be considered as variations of a single task; likewise, tasks composed generally of fine motor skills. Grouping the data in this manner provided a basis for estimating the difference between these types of tasks. A MOPPIV correction factor can then be estimated for each group. Task groupings are given in Table 9.

TABLE 9. Task Grouping for Analysis

Gross Motor Skills		Fine Motor Skills	
I, Remove Power Pack Transmission M109	II, Replace Power Pack Transmission M109	III, Remove Traverse M60 MG	IV, Replace Traverse M60 MG

III. RESULTS/DISCUSSION

The following tables (Tables 10-16) are the actual time for performing the major subdivisions of each task. Typically, this includes the removal and replacement times except in the recovery and M60 machine gun operations where this division was not appropriate. Where a team was able to accomplish a task more than once, multiple numbers are given. Times to perform the tasks in both BDU and MOPPIV are indicated. Details by event are provided in Appendix B.

TABLE 10. Remove/Replace M60A3 Power Pack

Team	Total Time, Minutes			
	BDU		MOPPIV	
	Remove	Replace	Remove	Replace
1	49.4	66.2	41.6	82.1
2	27.6	50.7	52.5	85.9
3	74.0	131.3	44.5	94.1
4	33.9	54.8	70.0	217.9
5	54.8	99.3	35.0	56.3

TABLE 11. Remove/Replace M60A3 Transmission

Team	Total Time, Minutes			
	BDU		MOPPIV	
	Remove	Replace	Remove	Replace
1	100.0	98.0	70.0	102.0
2	34.6	58.2	102.0	98.5
3	55.4	71.6	51.0	90.6
4	26.5	40.1	52.4 28.7	43.6 44.7
5	41.9	57.4	83.2	58.4

TABLE 12. Remove/Replace M109 Breech Block

Team	Total Time, Minutes			
	BDU		MOPPIV	
	Remove	Replace	Remove	Replace
1	3.4	4.7	9.8	8.2
	2.3	3.1	3.8	5.1
2	7.6	8.5	4.7	6.0
	2.7	3.0	4.5	6.8
3	3.2	3.8	3.4	18.4
	3.2	4.2	9.5	2.3
4	5.5	5.6	14.5	18.3
5	4.8	4.7	11.7	11.6
	4.2	3.1		

TABLE 13. Recovery of a M60A3 Tank

Team	Total Time, Minutes	
	BDU	MOPPIV
1	23.0	23.4
2	46.8	38.2
3	28.1	12.6
4	9.8	14.9
5	11.7	24.1

TABLE 14. Repair M60 Machine Gun

Team	Total Time, Minutes			
	BDU		MOPPIV	
	Barrel	Trigger	Barrel	Trigger
1	2.7	2.8	3.5	3.4
			3.2	2.8
			2.8	3.0
			2.4	1.5
			7.5	5.4
2	6.8	9.7	3.2	8.3
	3.0	2.3	4.2	3.6
	1.7	1.9	3.4	11.5
	1.8	2.4	4.2	6.2
			4.3	3.6
3	2.4	3.1	3.0	5.4
	2.4	2.1	3.2	7.3
	2.5	2.9	5.0	7.5
	2.3	2.2	3.7	4.8
			3.2	6.6
			3.0	3.4
4	2.3	2.7	3.0	3.3
	2.1	2.3	2.2	3.4
	1.9	2.2	3.7	3.5
	2.1	2.3	2.7	3.6
	1.6	1.9	2.9	2.8
	1.5	1.4		
	1.4	1.2		
5	3.1	1.5	3.2	3.3
	2.4	1.4	4.2	5.7
	2.6	1.3	2.8	6.0
	1.9	1.0	2.7	2.7
			2.9	7.5
			2.8	8.8
			2.2	9.7

TABLE 15. M901 ITV Traverse Mechanism

Team	Total Time, Minutes			
	BDU		MOPPIV	
	Disassembly	Reassembly	Disassembly	Reassembly
1	7.2	13.9	8.1	23.8
2	6.8	21.4	22.3	57.2
3	12.4	10.8	13.7	34.2
	5.2	5.1	8.4	12.7
4	6.6	8.4	17.8	21.9
5	4.5	7.5	13.0	16.5

TABLE 16. FADAC Printed Circuit Board

Team	Total Time, Minutes	
	BDU	MOPPIV
1	19.4	17.4
		24.0
		14.9
		27.8
2	33.3	19.5
	12.0	20.0
	6.2	22.0
		23.7
		11.7
		11.9
3	23.7	33.5
		54.7
		68.0
		28.7
4	28.5	23.5
	20.4	19.3
		20.2
		22.3
5	6.4	32.3
	6.9	19.3
	17.2	24.2
		22.8
		13.6
		12.0

IV. DATA ANALYSIS/DISCUSSION

The analysis is presented in four parts beginning with an example of the regression for an event in task 2. The regression results for all the tasks are then presented followed by a discussion of the MOPPIV correction factor for each task. Finally, a discussion is given for tasks grouped as either gross or fine motor functions.

1. Example of Regression Analysis

The example case will be replacment of the shroud during the removing/replacing of the M60A3 transmission accomplished during moderate temperature. All other tasks and events were likewise evaluated and are included in the results.

Replacing the shroud includes the placement of the shroud on the powerpack and the connection of the attachment bolts. The data for evaluation is given in Table 17, where team 1 replaced the shroud twice with the first occurrence in BDU in 7.8 minutes and the second occurrence in MOPPIV in 14.2 minutes. For this example, the resulting regression coefficients in Table 18, are "T_o," the practiced, unencumbered time, "a" the additional time for MOPPIV, plus or minus the standard deviation and "b" the additional time needed if the event is done for the first time plus or minus the standard deviation. Thus, the expected time for replacing the shroud is 5.8 minutes for a practiced unencumbered team. An additional 3.8 minutes is added to the total if the team was wearing MOPPIV for an expected time of 9.6 minutes. This additional MOPPIV time could be as much as 11.5 minutes (9.6+1.9) or as little as 7.7 minutes (9.6-1.9). No additional time is needed to complete this replacement for the first time because the coefficient is negative. In other events this first time correction is calculated the same as for the MOPPIV effect to determine the additional time needed. Resulting calculations for degraded effectiveness and MOPPIV correction factor with the associated probable range are given in Table 19.

TABLE 17. Data Used in Example Regression

Team	BDU	MOPPIV	1st Time
1	7.8	14.2	BDU
2	4.6	24.6*	MOPP
3	5.8	10.2	BDU
4	6.4	7.4	MOPP**
5	3.6	6.3	MOPP

* Data excluded due to the removal of items not associated with trial.
** Team is practiced in both uniforms.

TABLE 18. Regression Coefficients for Example

Coefficients
T_o = 5.8
a = 3.8±1.9
b = -0.5±2.0

In addition, the quotient resulting from "$T_o/(T_o + a)$" represents the degradation for wearing MOPPIV. That is, the unencumbered practiced time "T_o" divided by the total time for MOPPIV "$T_o + a$." Thus a team replacing the shroud in MOPPIV is degraded to 60 percent of their practiced, unencumbered ability, 5.8/(5.8+3.8)=0.60. In a similar calculation, the degradation for doing the job for the first time results from the quotient of "$T_o/(T_o+b)$." In this example no degradation was determined for doing the event for the first time. A team is degraded to 0.63 if replacing the shroud for the first time and in MOPPIV, where both MOPPIV and first time coefficients are added in the denominator, i.e. "T_o/T_o+a+b." The quantity "$(T_o+a)/T_o$" (which is the inverse of the degradation factor) is called the MOPPIV Correction Factor. This factor when multiplied by "T_o" gives the expected time to complete a task in MOPPIV. For this example the correction factor is 1.66. A probable range is determined by making the correction factor calculation using plus or minus the standard deviation, given for each coefficient. The estimated time for this event is then 5.8x1.66 or 9.6 minutes. The results calculated using this example are presented in Table 20.

TABLE 19. Calculations for Example

Calculations
T_o = 5.8
T_o +a = 9.6
T_o +b = 5.3
T_o +a+b = 9.1
$T_o/(T_o$ +a) = 0.60
$(T_o+a)/T_o$ = 1.66
$T_o/(T_o$ +b) = 1.09
a/T_o = 0.66

TABLE 20. Example Results

Effect of Wearing MOPPIV on Replacing the Shroud	
Degraded Effectiveness	0.60
MOPPIV Correction Factor Probable Range	1.7 1.3-2.0

Table 21 summarizes the regression results for all tasks by remove/replace, disassemble/reassemble functions. Regression results for each event for each task are in Appendix C.

2. **Regression results for all tasks**

a. **M60A3 Power Pack.** Replacing the power pack requires 1.4 more time when wearing MOPPIV. One event of this operation, however, required a correction of 2.7. In this operation the rail guides which direct the pack into the tank appear to be the cause. These guides could become bent with extended use resulting in an improper alignment. This observation could occur at any time but appeared to have more of an effect on the team when wearing MOPPIV. The resulting variation in time to perform this event reflected this difficulty. Correction Factors for the other events during this operation ranged from no correction to 1.7; the removal and replacement corrections are relatively equal.

b. **M60A3 Transmission.** MOPPIV corrections of 1.4 and 1.7 were needed for the events of removing and replacing the shroud respectively. The difference between these events appears to be in replacing the bolts on the shroud. The initial steps in starting these bolts requires extra time. Likewise, replacing the mounting bolts took 1.2 times longer. Evidently, replacing bolts requires the extra effort of first finding where the bolt fits and then starting the operation of threading. After the bolt is started (that is the tightening phase is started) the operation appears not to be degraded. Other events in this task were not affected by the wearing of MOPPIV, in fact, some events were performed in less time. This observation is believed to represent a natural variation between teams performing an operation not affected by wearing MOPPIV.

c. **M109 Breech Block.** The MOPPIV correction factors, for the six events in this task, ranged from 1.1 to 3.2. Replacing the breech was the most difficult taking 3.2 times longer in MOPPIV. This task requires both gross motor activity and some judgements made as the result of near vision and fine motor skills. The breech must be installed according to timing marks which determine whether the breech will lock and operate correctly. Setting the breech in place and alignment with these

TABLE 21. Regression Results by Task

Task	Unencumbered Term T_o	Clothing Correction a	Training Correction b	MOPPIV Factor/ PR*
M60A3 Power Pack				
Remove	33.1	5.7±5.9	24.8±5.9	1.2 1.0-1.4
Replace	57.4	17.0±12.7	20.7±13.1	1.3 1.1-1.5
M60A3 Transmission				
Remove	35.4	14.1±10.5	18.9±11.0	1.4 1.1-1.7
Replace	62.2	6.9±15.8	7.7±15.8	1.1 0.9-1.4
M109 Breech Block				
Disassembly	3.6	0.8±0.5	4.9±0.6	1.2 1.1-1.4
Reassembly	4.0	1.1±0.8	4.7±0.9	1.3 1.1-1.5
M60 MG				
Barrel Gp	2.3	1.0±0.3	1.3±0.5	1.4 1.3-1.6
Trigger Gp	2.2	2.8±0.6	2.2±1.1	2.3 2.0-2.6
M901 Traverse Mechanism				
Disassembly	5.3	5.7±2.0	5.8±2.0	2.1 1.7-2.5
Reassembly	9.9	15.3±8.1	4.9±8.1	2.5 1.7-3.4
Recover M60A3	11.7	10.9±13.8	15.2±14.1	1.9 0.8-3.1
FADAC Board	12.6	8.1±2.8	20.6±3.7	1.6 1.4-1.9

* PR = Probable range
Regression results by each event are in Appendix C.

marks are considered the cause for the increased correction factor. Removing the breech, by contrast, is corrected by a factor of 1.5; other than marking the location of the timing marks during this phase, theis operation requied no special adjustments. Generally, no difference was observed between removal and replacement events except the replacement of the breech itself; remaining events required 1.1 to 1.5 times longer to perform while wearing MOPPIV.

d. **Recover M60A3 Tank.** Opening the grill doors and removing the heat shield was the least effected recovery event while personnel were in MOPPIV, having a correction factor of 1.3 and a correction factor of 2.3 applied to all other events. As discussed earlier, the protective overboot was not worn during this exercise because of the hazard. The operation, however, could be performed if the boots were of an improved design. Specifically, if the mud and water entry into the boot was restricted by a better seal on the top, and better fit of the boot, it was thought that the boot could be worn. The alignment of the hitch with the tow bar was a difficult action. No flexibility is permitted during this operation, the driver of the M88 recovery vehicle must line-up the hitch exactly with the tow bar. In addition, disconnecting the final drives can be completed quickly in either uniform with a little good fortune depending upon how tight the drive is and the position from which disconnection is initiated. As a result the task can vary from trial to trial. This variation may account, in part, why a team wearing MOPPIV can complete this event in less time than a team wearing BDU.

e. **M60 Machine Gun.** The barrel group required 1.4 and 1.5 times longer to remove and replace while wearing MOPPIV. It was observed that this operation was completed with little difficulty other than the increase in time required to complete the procedure. Removing/disassembling and reassembly/replacing the trigger assembly, however, was another matter. The removal operation was corrected by 1.6. Replacing required a factor of 2.6. The replacement had a higher probable range reflecting the difficulty of this manual dexterity intense procedure. It should be noted, however, that the time required to complete these events was usually less than five minutes.

f. **M901 Traverse Mechanism.** Disassembling the traverse mechanism in MOPPIV took twice as long to complete while wearing MOPPIV. It took 1.7 times longer to reassemble the gears and 2.9 times as long to replace the outer gear, the snap rings and bevel washer. The gear assembly required that the mechanism be aligned to timing marks necessary for proper function. This alignment was completed correctly for all teams except one. During an assembly while wearing BDU the timing was missed and the gear box froze and required replacement. This observation confirmed the level of skill and care required to assemble this mechanism correctly. The correction factors observed represent the difference between complex disassembly and reassembly operations.

g. **FADAC Printed Circuit Board.** The operations on the resistor and the transistor are similar. The correction factor, however, is slightly different with a 1.5-1.7 calculated for the resistor and a 2.0 calculated for the transistor. The events were degraded by the wearing of MOPPIV but not apparently affected by the removal or replacement phase of the operation. It was evidently a little more difficult to replace the resistor. Other than the increase in time to perform the events the teams appeared to have little trouble in completing this task.

3. Aggregating Results

Combining events which are similar from the viewpoint of physiological requirements for task performance allows for several general comments about types of tasks. Such aggregations are important in relating individual quantified tasks to indirectly measured operational concepts such as "movement to the line." Aggregations, as the data becomes available, may be divided into such general areas as arming, maintaining, and fueling a system, such as a tank or aircraft.

In this analyses, tasks were grouped into "Gross Motor" and "Fine Motor Functions." Gross motor is defined as those tasks requiring the use of predominantly large muscles, arms, legs, and general whole body movements such as walking, running, etc. Fine motor functions include finger dexterity, tactile finger skills, precision movement and tasks with close vision hand-eye coordination.

The division of the gross and fine functions into removal and replacement tasks provides a further refinement of the types of tasks to be considered. Removal tasks have typically been considered to be easier to perform than replacement tasks. This concept is illustrated in Table 22, where the correction factor for replacement events are greater in both the gross and fine motor functions categories, although the correction to gross motor tasks is nearly the same. The difference between the removal and replacement correction factors for fine motor functions is appreciable with a 1.8 for removal tasks compared to 2.4 for replacement tasks. It is thought that manual dexterity and close coordination between hand and eye movements may have been the predominate reason for the difference.

4. Discussion

Teams wearing MOPPIV required more time to replace equipment than to remove it. Teams completing a task for the first time influenced the time needed to complete a task a second time. In this instance, the practice obtained by completing an event once was enough to improve the time for completing the event a second time. If the event was completed in BDUs first the MOPPIV times were affected, likewise, if the event was first completed in MOPPIV the BDU times were affected. This first-time effect can

TABLE 22. Grouped MOPPIV Effect

Gross Motor Functions		Fine Motor Functions	
I Remove	II Replace	III Remove	IV Replace
Power Pack Transmission M109	Power Pack Transmission M109	Traverse M60 MG	Traverse M60 MG
CF= 1.2	1.3	1.8	2.4
PR= 1.0-1.5	1.1-1.6	1.5-2.0	1.8-3.0
CF= Correction Factor			
PR= Probable Range			

confuse the interpretation of the data since subsequent times are often less. For example, the time to perform a task while wearing MOPPIV the first time is often longer than for a team completing the same task in MOPPIV after a prior performance wearing BDU. Likewise, the time to perform a task while wearing BDU is generally shorter for the team with prior experience wearing MOPPIV.

The difference between the correction factors for removal and replacement events may be influenced by other factors. One such factor, frequently observed, is that replacement events follow removal events. This was observed for teams wearing BDU or MOPPIV simply because the reassembly tasks apparently require more concentration than removal tasks. Fine motor functions evidently are more difficult to improve while wearing MOPPIV (bolt holes require alignment, the bolts require starting, attachments and connectors require positioning and alignment) but can be learned from a prior experience. As a result, a team always had the benefit from having participated in removing first. A team should gain a portion of experience for each task in this manner and the resulting degradation due to the first time effect would be expected to be less. Degradation due to wearing MOPPIV, however, would be expected to be greater due to the increase in difficulty.

V. SUMMARY/CONCLUSIONS

The quantification of the degradation of personnel performing in MOPPIV was determined for each maintenance operation and is summarized in Table 23. Events were weighted by the amount of time normally taken to complete an event and summed over all events to give an overall degradation for a task. The inverse of this degradation is the MOPPIV correction factor. Multiply the IDU time by this factor to get the estimated MOPPIV time.

TABLE 23. Correction Factors for MOPP IV

Task	Factor	Probable Range
M60A3 Power Pack		
Remove	1.2	1.0-1.4
Replace	1.3	1.1-1.5
M60A3 Transmission		
Remove	1.4	1.1-1.7
Replace	1.1	0.9-1.4
M109 Breech Block		
Remove	1.2	1.1-1.4
Replace	1.3	1.1-1.5
M60 Machine Gun		
Barrel Group	1.4	1.3-1.6
Trigger Group	2.3	2.0-2.6
M901 Traverse Mechanism		
Remove	2.1	1.7-2.5
Replace	2.5	1.7-3.4
Recover M60A3	1.8*	0.8-3.1
FADAC Circuit Board	1.6	1.4-1.9

*Without Boots

Other conclusions and observations based on the results of this study are:

- Teams completing tasks in MOPPIV demonstrated considerable ingenuity in overcoming difficulties. Some noteworthy examples were observed: picking up small parts with a tool, marking poorly defined timing marks with chalk, accommodating the lack of near vision while wearing the mask by getting closer, differentiating between small parts by improving the background contrast with light colored paper and the pre-sorting of tools.

- Replacement events for fine motor functions take longer than remove events.
- Fine motor skills are degraded to the same magnitude as gross motor skills.
- The protective overboot is a hazard in mud.
- Methods for simplifying or modifying tasks to accommodate wearing MOPPIV should be examined and incorporated into the training.

APPENDIX A

Climatic Conditions

Daily Temperature and Relative Humidity Record

During the exercise the temperature , relative humidity and general atmospheric condition were recorded at 30-minute intervals. Table A-1 gives the daily high, low and average records during the hours of the excerise. The exercise was conducted at Aberdeen Proving Ground, Maryland during April 1984. The high, low and average temperature and relative humidity are given in Table A-1.

TABLE A-1. Climatic Data

Day*	Degrees Celsius			% Relative Humidity		
	High	Low	Averge	High	Low	Average
02 Apr 84	16.7	5.2	13.0	75.0	43.0	62.6
03 Apr 84	16.2	11.2	14.3	65.0	32.0	44.0
04 Apr 84	9.0	8.1	8.7	93.0	72.0	80.4
05 Apr 84	19.0	14.0	16.4	95.0	65.0	83.1
06 Apr 84	13.0	9.9	12.0	61.0	42.0	50.3
07 Apr 84	8.6	7.0	7.6	74.0	56.0	64.8
09 Apr 84	12.3	6.2	9.9	53.0	28.0	38.2
10 Apr 84	15.4	4.1	10.3	86.0	30.0	53.9
11 Apr 84	15.4	7.0	11.3	58.0	28.0	42.5
12 Apr 84	19.8	8.7	15.4	79.0	38.0	54.4
13 Apr 84	20.0	12.2	16.1	69.0	50.0	59.2
16 Apr 84	16.7	10.0	13.1	92.0	64.0	79.7
17 Apr 84	18.3	9.4	14.8	91.0	48.0	65.4
18 Apr 84	17.8	8.3	13.0	92.0	53.0	72.7
19 Apr 84	16.1	8.3	11.4	71.0	43.0	59.9
20 Apr 84	16.5	11.7	14.8	65.0	43.0	49.8

TABLE A-1. Climatic Conditions (Continued)

Day*	Degrees Celsius			% Relative Humidity		
	High	Low	Average	High	Low	Average
24 Apr 84	13.8	9.6	12.5	89.0	50.0	59.1
25 Apr 84	16.4	11.8	14.0	57.0	48.0	52.0
26 Apr 84	20.8	13.0	18.0	68.0	35.0	49.3
27 Apr 84	18.9	11.0	15.5	83.0	56.0	67.3
28 Apr 84	15.0	11.0	12.7	75.0	61.0	68.3
01 May 84	17.9	14.3	15.9	43.0	30.0	37.8
02 May 84	21.3	11.4	17.2	60.0	31.0	37.3
03 May 84	16.0	13.5	14.6	83.0	69.0	74.4
04 May 84	21.3	18.2	19.9	85.0	70.0	77.6
07 May 84	13.4	12.0	12.6	91.0	82.0	86.8
AVERAGE	16.4	10.3	13.7	75.1	48.7	57.9

* 02 Apr 84 - 07 Apr 84 o Pull and Replace M60A2 Tank Engine

09 Apr 84 - 13 Apr 84 o ADVS 1790 Engine (Split Power Pack)

16 Apr 84 - 20 Apr 84 o Repair of the M60 Machine Gun
o Vehicle Recovery of M60A2 Tank
o Repair of a Printed Circuit Board

24 Apr 84 - 28 Apr 84 o Remove/Replace Breechblock (M109 Howitzer)

01 May 84 - 04 May 84 o Repair M901 Transverse Mechanism
07 May 84 (resumed)

APPENDIX B

Field Data

Field Data

The field measurements in minutes for each event in the seven maintenance tasks are included in this Appendix. A "B" represents battle dress uniform (BDU) and "M" represents mission oriented protective posture, level IV, (MOPPIV) all equipment worn and sealed. Events completed for the first time are indicated by an "*" by the appropriate entry. The corresponding tasks and tables are given in table B-1.

TABLE B-1. Field Data Tables

Task	Table
*Remove/Replace M60A3 Power Pack	B-2, B-3
*Remove/Replace M60A3 Transmission	B-4, B-5
*Remove/Replace M109 Breech Block	B-6, B-7
*Recover M60A3 Tank	B-8
*Remove/Repair M60 Machine Gun	B-9
*Repair M901 ITV Traverse Mechanism	B-10
*Repair FADAC Circuit Board	B-11

TABLE B-2. Remove M60A3 Power Pack

Team	Time in Minutes				
	Event				Total
	1	2	3	4	
1-B*	19.8	9.8	9.1	7.3	49.4
1-M	25.5	6.3	15.7	10.4	41.6
2-B	7.1	7.3	15.0	7.4	27.6
2-M*	13.8	18.7	31.2	14.3	52.5
3-B*	16.5	31.7	34.8	16.2	74.0
3-M	5.4	21.4	23.7	9.8	44.5
4-B	16.4	24.8	15.1	9.0	33.9
4-M*	26.0	40.8	48.6	16.2	70.0
5-B*	5.6	15.4	37.4	11.6	54.8
5-M	10.7	17.2	29.0	6.1	35.0

TABLE B-3. Replace M60A3 Power Pack

Team	Time in Minutes				
	Event				Total
	1	2	3	4	
1-B*	25.0	8.1	7.4	21.4	66.2
1-M	5.5	16.8	34.2	42.2	82.1
2-B	4.8	12.1	15.9	23.4	50.7
2-M*	5.5	26.0	43.4	24.6	85.9
3-B*	14.8	20.7	21.0	77.5	131.3
3-M	5.5	18.5	52.5	24.1	94.1
4-B	3.6	15.1	10.9	15.3	54.8
4-M*	13.9	80.0	87.5	106.5	217.9
5-B*	9.8	11.5	29.5	55.7	99.3
5-M	9.9	17.0	11.0	11.8	56.3

TABLE B-4. Remove M60A3 Transmission

Team	Time in Minutes				
	Event				Total
	1	2	3	4	
1-B*	8.4	52.0	43.2	5.8	100.0
1-M	7.0	23.0	39.9	3.0	70.0
2-B	3.2	11.9	18.8	18.5	34.6
2-M*	11.5	35.6	33.7	11.8	102.0
3-B*	3.8	21.5	40.8	1.2	55.4
3-M	4.5	15.1	31.0	1.6	51.0
4-B	3.2	12.6	10.8	1.0	28.5
4-M*	5.8	22.8	19.9	3.2	52.4
4-M	3.2	10.3	13.7	0.5	28.7
5-B	7.8	19.5	22.1	1.5	41.9
5-M*	6.3	37.5	26.7	9.2	83.2

TABLE B-5. Replace M60A3 Transmission

Team	Time in Minutes				
	Event				Total
	1	2	3	4	
1-B*	7.8	45.0	38.6	6.6	98.0
1-M	14.2	44.8	28.6	9.5	102.0
2-B	4.6	26.8	24.6	3.4	59.2
2-M*	24.6	28.2	39.0	5.1	98.5
3-B*	5.8	43.2	14.9	5.8	71.6
3-M	10.2	41.1	20.9	10.9	90.6
4-B	6.4	15.4	15.6	2.0	40.1
4-M*	2.0	15.5	22.2	0.9	43.6
4-M	7.4	17.5	16.8	1.7	44.7
5-B	3.6	25.6	19.3	7.3	57.4
5-M*	9.1	25.5	28.9	1.5	58.4

TABLE B-6. Remove M109 Breech Block

Team	Time in Minutes			
	Event			Total
	1	2	3	
1-B	1.6	1.5	0.4	3.4
	1.1	0.9	0.3	2.3
1-M	4.5*	4.5*	0.8*	9.8
	1.9	1.5	0.4	3.8
2-B	2.1*	4.5*	1.0*	7.6
	1.5	0.8	0.4	2.7
2-M	2.1	1.9	0.6	4.7
	2.6	1.4	0.6	4.5
3-B	1.9	1.2	0.5	3.2
	1.7	1.1	0.5	3.2
3-M	5.2*	2.4*	1.9*	9.5
	2.2	0.9	0.5	3.4
4-B	3.0	1.7	0.7	5.5
4-M	6.2	5.4	3.0	14.5
5-B	2.2	2.0	0.6	4.8
	2.0	1.8	0.5	4.2
5-M	4.3*	6.5*	0.9*	11.7

TABLE B-7. Replace M109 Breech Block

Team	Time in Minutes			
	Event			Total
	1	2	3	
1-B	0.6	1.3	2.8	4.7
	0.5	1.1	1.5	3.1
1-M	0.6*	2.4*	5.0*	8.2
	0.8	1.4	2.9	5.1
2-B	2.6*	2.6*	3.3*	8.5
	0.8	1.5	1.8	3.0
2-M	1.0	2.7	2.4	6.0
	0.8	1.8	4.2	6.8
3-B	0.5	0.8	2.4	3.8
	0.6	0.7	2.9	4.2
3-M	1.2*	11.9*	5.[illegible]	18.4
	0.6	0.9	0.7	2.3
4-B	1.1	2.0	2.4	5.6
4-M	7.5	7.0	3.7	18.3
5-B	0.6	1.3	2.8	4.7
	0.6	1.1	1.5	3.1
5-M	1.7*	5.8*	4.2*	11.6

TABLE B-8. Recovery of a M60A3 Tank

Team	Time in Minutes				
	Event				Total
	1	2	3	4	
1-B*	4.3	3.5	13.0	2.5	23.0
1-M	5.4	4.1	6.8	2.3	23.4
2-B*	10.0	8.9	21.7	8.8	46.8
2-M	16.5	5.0	11.9	4.8	38.2
3-B*	5.1	5.9	12.1	1.2	28.1
3-M	4.4	7.0	1.9	1.3	12.6
4-B*	4.9	2.7	1.8	0.4	9.8
4-M	11.3	2.2	4.9	2.3	14.9
5-B	4.9	3.5	2.3	1.2	11.7
5-M	13.6	3.4	1.9	2.8	24.1

TABLE B-9. Repair M60 Machine Gun

Team	Time in Minutes					
	Barrel Group			Trigger Group		
	Event		Total	Event		Total
	1	2		1	2	
1-B	1.6	1.1	2.7	1.0	1.8	2.8
1-M	1.7	1.8	3.5	1.1	2.3	3.4
	1.7	1.5	3.2	0.8	2.0	2.8
	1.5	1.3	2.8	0.9	2.2	3.0
	1.3	1.1	2.4	0.4	1.1	1.5
	5.2	2.3	7.5	1.7	3.7	5.4
2-B	2.8*	4.0*	6.8*	1.5*	8.2*	9.7
	1.2	1.8	3.0	0.9	1.5	2.3
	1.1	0.6	1.7	0.7	1.1	1.9
	1.0	0.8	1.8	0.6	1.8	2.4
2-M	1.4	1.8	3.2	1.1	7.3	8.3
	2.5	1.7	4.2	0.6	2.9	3.6
	1.8	1.6	3.4	1.0	10.5	11.5
	2.2	2.0	4.2	1.0	5.2	6.2
	1.9	2.4	4.3	1.1	2.5	3.6

TABLE A-9. Repair M60 Machine Gun (Continued)

Team	Time in Minutes					
	Barrel Group			Trigger Group		
	Event		Total	Event		Total
	1	2		1	2	
3-B	1.5	0.9	2.4	0.8	2.3	3.1
	1.3	1.1	2.4	0.8	1.3	2.1
	1.3	1.2	2.5	0.6	2.2	2.9
	1.2	1.0	2.3	0.5	1.7	2.2
3-M	1.8*	1.3*	3.0*	1.5*	3.9*	5.4
	1.7	1.5	3.2	1.2	6.2	7.3
	2.5	2.5	5.0	1.6	5.9	7.5
	1.7	2.0	3.7	1.3	3.6	4.8
	1.7	1.5	3.2	1.3	5.3	6.6
	1.5	1.5	3.0	1.4	2.0	3.4
4-B	1.2*	1.1*	2.3*	0.7*	2.0*	2.7
	1.0	1.1	2.1	0.8	1.5	2.3
	1.0	0.9	1.9	0.6	1.6	2.2
	1.1	1.0	2.1	0.6	1.7	2.3
	0.8	0.8	1.6	0.5	1.3	1.9
	0.6	0.9	1.5	0.4	0.9	1.4
	0.7	0.8	1.4	0.4	0.8	1.2
4-M	1.3	1.8	3.0	0.8	2.4	3.3
	0.8	1.3	2.2	1.0	2.4	3.4
	1.9	1.8	3.7	1.0	2.5	3.5
	1.0	1.7	2.7	0.9	2.7	3.6
	1.0	1.9	2.9	0.8	2.0	2.8
5-B	1.7	1.4	3.1	0.7	0.8	1.5
	1.0	1.3	2.4	0.5	0.9	1.4
	1.2	1.4	2.6	0.5	0.8	1.3
	0.8	1.1	1.9	0.3	0.7	1.0
5-M	1.2	1.9	3.2	0.9	2.3	3.3
	1.3*	2.9*	4.2*	1.0*	4.7*	5.7
	1.3	1.6	2.8	0.8	5.2	6.0
	1.1	1.6	2.7	0.9	1.8	2.7
	1.2	1.7	2.9	1.3	6.3	7.5
	1.3	1.5	2.8	0.8	8.0	8.8
	1.1	1.1	2.2	0.7	9.0	9.7

TABLE B-10. Repair M901 ITV Traverse Mechanism

Team	Time in Minutes					
	Event					
	Disassembly			Reassembly		
	1	2	Total	1	2	Total
1-B*	3.0	4.2	7.2	7.0	6.9	13.9
1-M	4.2	3.9	8.1	5.0	18.8	23.8
2-B	2.7	4.1	6.8	2.4	19.0	21.4
2-M*	12.5	9.8	22.3	7.0	50.2	57.2
3-B	6.9*	6.5*	12.4*	3.5*	7.4*	10.8
	2.7	2.5	5.2	2.0	3.1	5.1
3-M	8.1	5.6	13.7	6.0	28.1	34.2
	5.3	3.1	8.4	3.3	9.5	12.7
4-B	4.7	1.8	6.6	0.8	7.6	8.4
4-M*	6.8	10.9	17.8	6.8	15.0	21.9
5-B	a	a		a	a	
5-M*	5.8	7.2	13.0	1.9	15.6	16.5

a = no data

Discussion

Certain data points required review particularly data points associated with comments or events which influenced the time to complete a given event. As a result of this review, some of the data points were not included in the regression analysis. All regression estimates represent the best selection of data as determined by the video tape record and the comments of the military observer at the time of the event.

Data obtained from the third team in BDU during the remove/replace power pack task (Tables B-2 and B-3) are not included in the analysis because of a rapid change in the weather. Specifically it began to rain. As the rain increased in intensity it was interesting to note that the time to complete events increased. All times for team four in MOPPIV were not included due to multiple stops for safety reasons and a bent alignment bar on the base of the power pack which prevented replacement.

From the remove/replace transmission task (Tables B-4 and B-5), three event times were removed from analysis. Team one in MOPPIV, event 6, (44.8 min) was not considered due to stripped threads on a fuel return line, and some question on the installation of numerous bolts and washers. Team two in MOPPIV, event 5, (24.6 min) was also eliminated due to the incorrect removal of items which required extra time to replace. Team 5 in MOPPIV,

TABLE B-11. Repair FADAC Circuit Board

Team	Time in Minutes					
	Event 1	2	3	4	5	Total
1-B	4.4	6.8	8.2	nd	nd	19.4
1-M	4.3	5.1	0.9	3.6	3.6	17.4
	3.8	5.1	15.2	nd	nd	24.0
	5.6	3.1	6.2	nd	nd	14.9
	6.5	4.1	5.1	6.5	5.7	27.8
2-B	12.0	9.3	2.2	4.4	5.1	33.3
	3.7	2.7	1.7	1.3	2.7	12.0
	2.0	0.8	0.4	1.8	1.2	6.2
2-M	7.2	3.7	0.4	2.8	5.5	19.5
	9.0	2.8	0.7	3.0	4.5	20.0
	8.7	2.3	0.3	6.7	4.0	22.0
	5.3	1.0	0.3	1.3	5.9	23.7
	4.8	1.8	1.5	1.0	2.5	11.7
	2.8	2.5	2.7	1.6	3.3	11.9
3-b	7.2	5.9	1.7	6.5	2.3	23.7
3-M	9.4	10.8	1.3	7.6	4.5	33.5
	10.9	19.1	5.6	12.8	6.3	54.7
	7.0	13.0	15.5	12.0	21.0	68.0
	6.4	5.5	6.1	3.3	7.3	28.7
4-B	12.2	2.1	2.3	6.8	5.1	28.5
	4.5	6.3	1.3	4.9	3.4	20.4
4-M	4.5	3.5	1.8	8.8	4.8	23.5
	3.4	2.6	1.0	6.4	6.0	19.3
	3.4	3.4	1.9	6.6	4.9	20.2
	3.8	2.8	3.4	5.7	6.6	22.3
5-B	0.5	0.5	0.4	1.9	3.1	6.4
	1.0	0.9	0.9	1.3	2.8	6.9
	2.8	3.4	3.1	4.0	3.8	17.3
5-M	6.5	4.3	8.9	5.0	7.7	32.3
	4.5	2.8	2.3	3.6	6.1	19.3
	4.3	2.6	3.4	7.9	6.0	24.2
	3.4	3.4	2.8	4.7	8.5	22.8
	4.4	2.8	0.8	2.5	3.1	13.6
	2.2	1.8	1.2	2.9	3.9	12.0

nd = no data

One series of data points was excluded from the recovery of the M60A3 tank. The first team in MOPPIV encountered extreme difficulty in using the MOPP boots, in that, they proved to be hazardous in the deep mud of the recovery field. The boots slipped off and to the side and created an unworkable situation. All recovery operations in MOPPIV after this first experience

were without the boots. Another difficulty in the analysis of the recovery task was that all but one team started while wearing BDU. The single team which started while wearing MOPPIV began and made a false start and began again. Because of this start this team was considered to have been practiced simply because they had learned something about the task, the situation, the ground, the water, where the tank would be, etc. As a result, the correction factor may contain some of the "first time" effect. The estimation for making the recovery, however, should be within the probable range indicated.

APPENDIX C

Regression Results by Task and Event

Regression Results by Task and Event

The regression results by task and event are contained in this appendix. Tables include "a/T_o," or fractional increase in time due to MOPPIV for each event in each task, and regression coefficients and calculations by event for each task. Field measurements are given in appendix B. The corresponding tables and figures for each task are given in table C-1.

TABLE C-1. Tables for Regression Results

Task	Tables
■ Remove/Replace M60A3 Power Pack	C2-C4
■ Remove/Replace M60A3 Transmission	C5-C7
■ Remove/Replace M109 Breech Block	C8-C9
■ Recover M60A3 Tank	C10-C11
■ Remove/Repair M60 Machine Gun	C12-C13
■ Repair M901 ITV Traverse Mechanism	C14-C15
■ Repair FADAC Printed Circuit Board	C16-C17

TABLE C-2. Remove/replace M60A3 Power Pack

Event	Tasks	a/T_o
1	Cover	0.15 ± 0.52
2	Turret Connections	0.10 ± 0.40
3	Accessory Connections	0.52 ± 0.48
4	Remove Power Pack	0.29 ± 0.25
5	Replace Deck	-0.34 ± 0.67
6	Replace Battery and Engine Accessories	0.69 ± 0.25
7	Replace Engine and Accessories	1.69 ± 0.87
8	Replace Power Pack	-0.03 ± 0.49

TABLE C-3. Remove/Replace M60 Power Pack, Regression Coefficients

	Event			
	1	2	3	4
T_o	12.0	14.5	15.0	7.3
a	1.8±6.2	1.4±5.8	7.8±7.2	2.1±1.8
B	0.5±6.4	-0.3±6.0	8.3±7.5	3.1±1.8
r*r	0.02	0.02	0.28	0.41
T_o ÷a	13.8	15.9	22.8	9.4
T_o ÷B	12.5	14.2	23.3	10.4
T_o ÷a÷B	14.3	15.6	31.1	14.4
T_o/T_o÷a	0.87	0.91	0.66	0.78
T_o/T_o÷B	0.96	1.00	0.64	0.70
CF	1.2	1.1	1.5	1.3
PR	0.6-1.67	0.7-1.5	1.0-2.0	1.0-1.5

CF = Correction Factor
PR = Probable Range

TABLE C-4. Remove/Replace M60A3 Power Pack, Regression Coefficients, Continued

	Event			
	5	6	7	8
T_o	7.3	11.3	12.6	23.8
a	-2.5±4.9	7.8±2.8	21.2±11.0	-0.59±11.7
B	6.9±5.0	0.7±2.8	7.5±11.4	10.5±12.1
r*r	0.35	0.61	0.43	0.14
T_c÷a	4.8	19.1	33.8	23.1
T_o÷B	14.2	12.0	20.1	34.3
T_o÷a÷B	11.6	19.8	41.3	33.6
T_o/T_o÷a	1.50	0.59	0.37	1.03
T_o/T_o÷B	0.51	0.94	0.63	0.69
CF	0.7	1.7	2.7	1.0
PR	sml-1.3	1.4-1.9	1.8-3.6	0.5-1.5

CF = Correction Factor
PR = Probable Range
sml = small

TABLE C-5. Remove/replace M60A3 Transmission

Event	Task	a/T_o
1	Remove Shrouds	0.41 ± 0.41
2	Remove Accessories	-0.13 ± 0.39
3	Remove Mounting Bolts	-0.04 ± 0.29
4	Separate	-0.13 ± 0.74
5	Replace Shrouds	0.66 ± 0.33
6	Replace Accessories	0.02 ± 0.36
7	Replace Mounting Bolts	0.22 ± 0.28
8	Replace Transmission	-0.04 ± 0.41

TABLE C-6. Remove/replace M60A3 Transmission, Regression Coefficients

	Event			
	1	2	3	4
T_o	3.4	16.5	26.6	5.3
a	1.4±1.4	-2.1±6.4	-1.1±7.7	-0.7±3.9
B	3.2±1.4	17.6±6.5	0.9±1.6	0.5±3.9
r*r	0.43	0.51	0.04	0.01
T_o÷a	4.8	14.4	25.5	4.6
T_o÷B	6.6	34.1	27.5	5.8
T_o÷a÷B	8.0	32.0	26.4	5.1
T_o/T_o÷a	0.71	1.15	1.04	1.15
T_o/T_o÷B	0.52	0.48	0.97	0.91
CF	1.4	0.9	1.0	0.9
PR	1.0-1.8	0.5-1.3	0.7-1.3	sml-1.6

CF = Correction Factor
PR = Probable Range
sml = small

TABLE C-7. Remove/replace M60A3 Transmission, Regression Coefficients, cont.

	Event			
	5	6	7	8
T_o	5.8	24.9	18.8	5.6
a	3.8±1.9	0.5±9.0	4.1±5.2	-0.2±2.3
B	-0.5±24.0	10.4±8.7	4.1±5.2	-1.0±2.3
r*r	0.42	0.23	0.19	0.02
T_o+a	9.6	24.5	22.9	5.4
T_o+B	5.3	35.3	25.1	4.6
T_o+a+B	9.1	34.9	29.2	4.4
T_o/T_o+a	0.60	1.02	0.82	1.04
T_o/T_o+B	1.09	0.71	0.75	1.22
CF	1.7	1.0	1.2	1.0
PR	1.3-2.0	0.7-1.4	1.0-1.5	0.5-1.4

CF = Correction Factor
PR = Probable Range

TABLE C-8. Remove/replace M109 Breech Block

Event	Task	a/T_o
1	Remove Damper	0.53 ± 0.24
2	Remove Firing Mechanism	0.07 ± 0.36
3	Remove Breech Block	0.45 ± 0.68
4	Replace Spindle	0.30 ± 1.21
5	Replace Breech	2.18 ± 1.18
6	Replace Firing Mechanism/Damper	0.22 ± 0.22

TABLE C-9. Remove/replace M109 Breech Block

	Event					
	1	2	3	4	5	6
T_o	1.7	1.4	0.44	0.66	1.1	2.3
a	0.9±0.4	0.1±0.5	0.2±0.3	0.2±0.8	2.4±1.3	0.5±0.5
B	2.0±0.5	3.2±0.5	0.9±0.3	2.0±0.9	2.7±1.4	1.6±0.5
r*r	0.73	0.78	0.51	0.34	0.47	0.57
T_o÷a	2.6	1.5	0.64	0.86	3.5	2.8
T_o÷B	3.7	4.6	1.3	2.7	3.8	3.9
T_o÷a÷B	4.6	4.7	1.5	2.9	6.2	4.4
T_o/T_o÷a	.65	0.93	0.69	0.77	0.31	0.82
T_o/T_o÷B	.46	0.30	0.35	0.25	0.29	0.59
CF	1.5	1.1	1.5	1.3	3.2	1.2
PR						

CF = Correction Factor
PR = Probable Range
sml= small

TABLE C-10. M60A3 Tank Recovery

Event	Task	a/T_o
1	Position M88 and Hook Tow Bar	1.33 ± 0.94
2	Open Grill Doors and Heat Shields	0.26 ± 0.77
3	Disconnect Final Drives	1.26 ± 3.22
4	Secure Doors and Shield	1.33 ± 2.67

TABLE C-11. Recover a M60A3 Tank, Regression Coefficients

	Event			
	1	2	3	4
T_o	4.9	3.5	2.3	1.2
a	6.5±4.6	0.9±2.7	2.9±7.4	1.6±3.2
B	1.2±4.6	1.7±2.5	9.8±7.4	2.0±3.2
r*r	0.41	0.08	0.33	0.06
T_o+a	11.4	4.4	5.2	2.8
T_o+B	6.1	5.2	12.1	3.2
T_o+a+B	12.6	6.1	15.0	4.8
T_o/T_o+a	0.43	0.80	0.44	0.43
T_o/T_o+B	0.80	0.67	0.19	0.38
CF	2.3	1.3	2.3	2.3
PR	1.4-3.3	0.5-2.0	sml-5.5	sml-5.0

CF = Correction Factor
PR = Probable Range
sml= Small

TABLE C-12. Repair M60 Machine Gun

Event	Task	a/T_o
1	Remove and Disassemble Barrel Group	0.42 ± 0.17
2	Reassemble and Replace Barrel Group	0.55 ± 0.18
3	Remove and Disassemble Trigger Assembly	0.63 ± 0.16
4	Reassemble and Replace Trigger Assembly	1.67 ± 0.40

TABLE C-13. Repair M60 Machine Gun, Regression Coefficients

	Event			
	1	2	3	4
T_o	1.2	1.1	.64	1.5
a	0.5±0.2	0.6±0.2	0.4±0.1	2.5±0.6
B	0.4±0.4	0.9±0.3	4.9±0.1	1.9±1.1
r*r	0.12	0.33	0.38	0.30
T_o+a	1.7	1.7	1.0	4.0
T_o+B	1.6	2.0	1.0	3.4
T_o+a+B	2.1	3.6	1.4	5.9
T_o/T_o+a	0.71	0.65	0.62	0.38
T_o/T_o+B	0.75	0.55	0.62	0.38
CF	1.4	1.5	1.6	2.6
PR	1.2-1.6	1.4-1.7	1.5-1.8	2.3-3.1

CF = Correction Factor
PR = Probable Range

TABLE C-14. Remove/replace M901 ITV Traverse Mechanism

Event	Task	a/T_o
1	Remove Outer Gear,Snap Ring and Bevel Washer	0.91 ± 0.44
2	Remove Gear	1.14 ± 0.45
3	Reassemble Gears and Replace	0.71 ± 0.54
4	Replace Outer Gear, Snap Ring and Bevel Washer	1.83 ± 0.99

TABLE C-15. Remove/replace M901 ITV Traverse Mechanism, Regression Coefficients

	Event 1	2	3	4
T_o	3.2	2.2	2.4	7.5
a	2.9±1.4	2.5±1.0	1.7±1.3	13.7±7.4
B	2.1±1.4	4.0±1.0	1.8±1.3	3.3±7.4
r*r	0.46	0.77	0.35	0.32
T_o+a	6.1	4.7	4.1	21.2
T_o+B	5.3	6.2	4.2	10.8
T_o+a+B	9.2	8.7	5.9	24.5
T_o/T_o+a	0.52	0.47	0.59	0.35
T_o/T_o+B	0.60	0.35	0.57	0.69
CF	1.9	2.1	1.7	2.9
PR	1.5-2.3	1.7-2.6	1.2-2.3	1.8-3.8

CF = Correction Factor
PR = Probable Range

TABLE C-16. FADAC Printed Circuit Board Repair

Event	Task	a/T_o
1	Remove Protective Coating	0.32 ± 0.24
2	Remove Resistor	0.46 ± 0.46
3	Remove Transistor	0.94 ± 0.78
4	Replace Resistor	0.72 ± 0.38
5	Replace Transistor	0.93 ± 0.43

TABLE C-17. FADAC Printed Circuit Board Repair, Regression Coefficients

	Event				
	1	2	3	4	5
T_o	3.8	2.8	1.8	2.9	3.0
a	1.2±0.9	1.3±1.3	1.7±1.4	2.1±1.1	2.8±1.3
B	6.0±1.2	5.2±1.9	1.9±2.0	3.3±1.5	1.2±1.8
r*r	0.45	0.20	0.06	0.20	0.15
T_o÷a	5.0	4.1	3.5	5.0	5.8
T_o÷B	9.8	8.0	3.7	6.2	4.2
T_o÷a÷B	11.0	9.3	5.2	9.3	7.0
T_o/T_o÷a	0.76	0.68	0.51	0.58	0.52
T_o/T_o÷B	0.39	0.35	0.53	0.47	0.71
CF	1.3	1.5	2.0	1.7	1.9
PR	1.1-1.6	1.0-1.9	1.2-2.7	1.3-2.1	1.5-2.4

CF = Correction Factor
PR = Probable Range

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